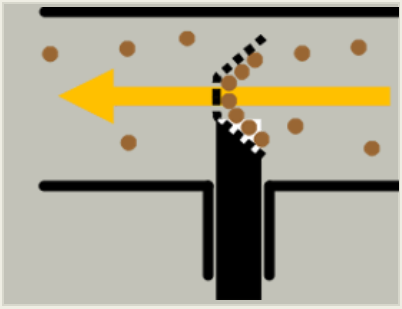
Integrated Sample Acquisition Drill and Pneumatic Sample Delivery for Ocean Worlds

Completed Technology Project (2017 - 2018)

Project Introduction

Scientific Goals & Objectives: One of the most pressing questions in exploration is whether life exists or existed anywhere else in the universe. Water is a critical prerequisite for life as we-know it, thus targets for extraterrestrial life are bodies that have or had liquid water, i.e. Ocean Worlds such as Titan or Europa. Due to the large radiation fluxes at Europa, or the possibility for burial by aeolian sediment at Titan, the search for life demands the capability to sample subsurface locations. Methodology: State-of-the-art life detection instruments require a sampling system to deliver a subsurface sample to the instrument (non-contact instruments alone are insufficient). A sampling operation normally has four steps: 1. sampler deployment, 2. material excavation, 3. sample capture, and 4. sample delivery. These steps have to be considered in a context of the entire system rather than a stand-alone operation. A review of the sampling approaches deployed on other bodies show that scoops and drills were methods of choice. Scoops were used for sampling loose materials while drills for competent materials. Many adaptations of terrestrial excavation approaches and numerous exotic systems have been proposed and developed in the past. Yet, rarely can they compete with the scoop/drill approach, unless in unique scenarios such as the Touch and Go operations that last seconds. We developed dozens of sampling systems: scoops, trenchers, rasps, harpoons, piercing blades, spinning cutters, clams and others. However, only hammer drills solved all the challenges related to excavation, sample capture, and drop off. In addition, drills penetrated deeper than other systems and were easily scaled up or down to capture a desired sample volume from depth. We therefore propose to develop a drill-based Integrated Sampling System (ISS) for Titan (the system or its subsystems would be applicable to other Ocean Worlds with some level of modification). To date, no sampling systems have been developed that could successfully deal with a range of Titan's cryogenic materials: rocks, soils, sticky soils, and liquids (hydrocarbons on Titan). The proposed ISS captures the most promising approaches developed over the past 10 years at Honeybee into a single, fully integrated system. The drill will be baselined to reach 20 cm in depth and capture up to 20 samples 1 cc each, or fewer samples of greater volume. In Y1, we will perform numerous risk reduction tests using existing TRL 4/5 drilling system and various breadboards under Titan environments with appropriate analog materials. All tests will be done at -20 °C walk-in freezer with LN2 sample cooling (90K). Heat and mass transfer mechanics are sufficiently similar at 1 atm compared with Titan conditions to allow confident scaling of test results to Titan's 1.45 atm, 95% N2 atmosphere. We will study deployment options, drill bit configurations, drilling methods, and sample transfer and drop-off methods. Lessons from this test-heavy phase will be used to trade various architectures and subsequently to develop and test a TRL6 ISS in Y2. Our experience with the Mars Phoenix hardware for Mars's special regions (Planetary Protection, cat IVb) will guide materials and design choices. The data will be available to public (via publications) and future missions. The ISS, once at TRL6, would be easily



"Lacrosse stick" is used to capture a sample in the 'vacuum

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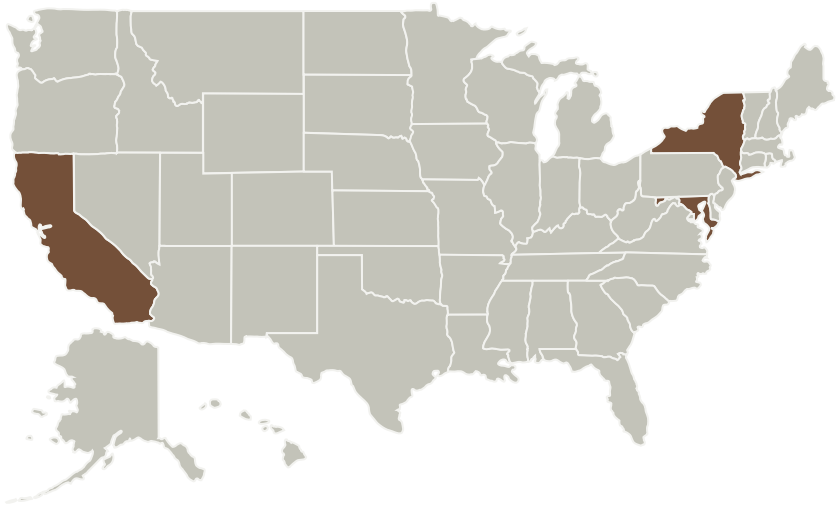
infused into future missions, with little to no modifications. Team: Our team brings expertise in Ocean Worlds environments and science goals, is experienced in the development and testing of planetary samplers, as well as in developing of flight hardware and operating of such flight hardware in actual missions. Relevance to this call: The proposal directly addresses the call: COLDTech seeks to "develop and advance sample acquisition, delivery and analysis systems. Sample distribution systems capable of parsing and delivering samples to multiple instruments are also of interest".

Anticipated Benefits

1) Enable the system to handle the inevitable issues of sticky samples, 2) Enable small volume analysis from a large input sample volume and deliver the sample to a chemical analysis instrument in small (~10 mm) diameter cups, and 3) Deliver a sample from the surface to an instrument that sits in the middle of a spacecraft.

Primary U.S. Work Locations and Key Partners



Organizations Performing Work	Role	Type	Location
Honeybee Robotics, Ltd.	Lead Organization	Industry	Pasadena, California

Organizational Responsibility

Responsible Mission Directorate:

Science Mission Directorate (SMD)

Lead Organization:

Honeybee Robotics, Ltd.

Responsible Program:

Concepts for Ocean Worlds Life Detection Technology

Project Management

Program Director:

Carolyn R Mercer

Program Manager:

Carolyn R Mercer

Principal Investigator:

Kris Zacny

Co-Investigators:

Gale L Paulsen
Ralph D Lorenz
Chris Chapman

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Primary U.S. Work Locations	
California	Maryland
New York	

Project Transitions

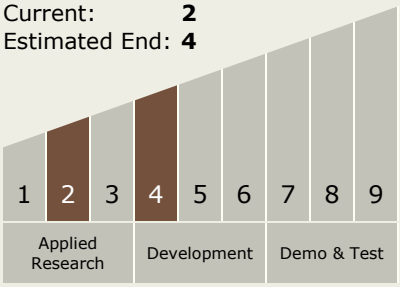
January 2017: Project Start

December 2018: Closed out

Closeout Summary: Playing Lacrosse on Titan Honeybee Robotics has developed a pneumatic based sample acquisition and transfer system that is self-metering, gravity agnostic, works with sticky materials, and is flexible in terms of delivery location. The system is designed to operate on planetary bodies both with and without an atmosphere. The "vacuum and lacrosse stick" concept now form the backbone of the sampling system for Dragonfly, selected in 2019 as NASA's next New Frontiers mission. The sampling system, DrACO (Drill for Acquisition of Complex Organics), consists of two redundant drills, a carousel with dozens of cups (modified lacrosse nets), and a vacuum system with two redundant blowers. The drills and blowers are in a cross-strapped configuration as any of the two drills can be used with any of the two blowers. The sampling operation starts with a drill cutting into Titan's surface to grind up material. The vacuum system then sucks up material into a transfer tube, while the cup with a lacrosse net captures some of this material for analysis. The carousel subsequently moves the cup into one of the two onboard instruments (a gas chromatography mass spectrometer or a laser desorption mass spectrometer) for analysis. The technology has also been demonstrated for applicability to airless bodies such as Earth's Moon. In these cases, compressed gas is brought from Earth to mobilize surface material and create this dusty flow. PlanetVac and Pneumatic Sampler are utilizing this approach and will fly to the Moon in 2023 using NASA Commercial Lunar Payload Service (CLPS) and to the Martian moon, Phobos, in 2024, respectively.

Technology Maturity (TRL)

Start: **2**
Current: **2**
Estimated End: **4**



Technology Areas

Primary:

- TX08 Sensors and Instruments
  - TX08.3 In-Situ Instruments and Sensors
    - TX08.3.4 Environment Sensors

Target Destination

Others Inside the Solar System

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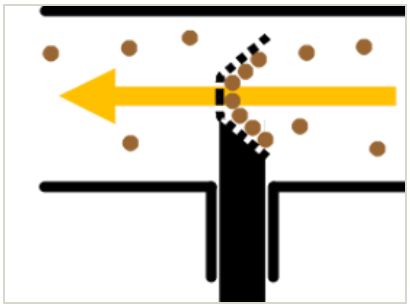
Images



"Lacrosse stick" concept
"Lacrosse stick" is used to capture a sample in the 'vacuum
(https://techport.nasa.gov/image/145168)